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Curriculum Guide: Environmental Technology Transfer

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CURRICULUM GUIDE

ENVIRONMENTAL TECHNOLOGY TRANSFER

Prepared by

Environmental Institute
for
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6108 CURICULUM GUIDE: ENVIRONMENTAL TECHNOLOGY TRANSFER

This report is part of the National Network for Environmental Management Studies (NNEMS) conducted under the auspices of the Office of Cooperative Environmental Management -U. S. Environmental Protection Agency. The potential for innovation in the waste management industry is tremendous. Recycling programs are being developed and test sites using new land treatment technology for waste water already exist. The current high cost of waste disposal and liability insurance are sure to spur additional innovation in waste water management.

To facilitate the development of innovative technology, an aggressive approach to environmental technology transfer should be established. The Curriculum presented in this report is a base from which to develop a strong environmental technology transfer program.

The objectives of the Environmental Technology TransferCurriculum are: 1) to promote critical thinking in the determination of problems; 2) develop an attitude that promotes innovation and 3) develop methods by which innovative technology can be shared.

The curriculum for environmental technology transfer provides an outline of pertinent subjects and a brief synopsis. Appendices at the end of the curriculum provide additional background material on selected subjects

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The contents are essentially as received from the author. The opinions, findings, and conclusions expressed are those of the author and not necessarily those of the Environmental Protection Agency. Mention, if any, of company, process, or product names is not to be considered as an endorsement by the U. S. Environmental Protection Agency.

Curriculum for Environmental Technology Transfer

For years the waste management industry has been controlled by primitive attitudes. The principle form of management was to dilute the waste to an acceptable level and then dispose of it on or in the ground. An excellent example of how little waste management practices have changed is found in waste water management. Waste water management is based on the practice of filtration and aeration. This is the method by which waste water is currently processed and it has been processed in this manner since the first sanitary sewerage system was built in Hamburg, Germany in 1843. Recent innovations in waste water management are directed more towards effluent uses like groundwater recharge, aquaculture, and possible industrial uses. Very little new technology is being applied to waste water treatment, and the development of new technology that is occurring is happening mostly overseas. The United States treats waste management as an extension of the garbage business.

Another area of waste management that is of concern is the relationship between environmental and production departments. A laissez-faire attitude is the prevailing attitude in industry towards by-products produced. The lack of communication between environmental and production engineers results in instances of contamination by hazardous by-products that may have been preventable.

Future potential for innovation in the waste management industry is tremendous. Recycling programs are being developed and test sites using new land treatment technology for waste water already exist. The current high cost of waste disposal and liability insurance are sure to spur additional innovation in waste management.

To facilitate the development of innovative technology, an aggressive approach to environmental technology transfer should be established. The curriculum presented here is a base from which to develop a strong environmental technology transfer program.

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Curriculum Outline for Environmental Technology Transfer

I. Environmental Technology Transfer

A. Definition

Technology Transfer is the dissemination of information or innovation to those who can apply it. Technology Transfer applied to the environmental field is multi-faceted. It includes research, education, and information dissemination. The first component of an Environmental Technology Transfer program is short-term research. Research may be on new technologies. However, the primary emphasis is on ways to adapt existing technology to new applications. Education is the second integral part of Environmental Technology Transfer. People must know what problems exist, what efforts are currently underway to solve problems, and what is required or allowed under existing laws. Finally, information dissemination is essential. The best innovative technology would be useless unless businesses which can apply the technology are informed about its existence and capabilities.

B. Historical Aspect

Plato was an early proponent of Technology Transfer. He recognized that small, intimate groups are more conducive to innovation and exchange of ideas. This is currently being applied by industry in the form of quality circle groups.

C. Idea of Technology Transfer

Technology Transfer requires communication between researchers and users. To be successful, both parties must benefit (users receive new technology, researchers receive monetary rewards). A roadblock to Technology Transfer is the long, arduous process required to obtain federal permits to apply new technology (or old technology in a new way).

D. Technology Transfer Legislation

In the 1960's and 1970's a trend towards Japanese dominance in electronic and computer technology became evident. In an effort to reverse this trend the Federal Government has enacted the following legislation to support and promote technology transfer within the United States.

1. Stevenson-Wydler Technology Innovation Act of 1980 (15 U.S.C. 3710)
2. Patent and Trademark Amendments of 1980 (15 U.S.C. 200)
3. Technology Transfer Act of 1986 (P.L. 99-502)
4. Executive Order 12591, "Facilitating Access to Science and Technology" (1987)
5. Superfund Innovation Technology Evaluation (SITE) set up by the Superfund Amendments and Reauthorization Act of 1986 (SARA)

E. Changing Role of the Environmental Protection Agency

The Environmental Protection Agency wants to work with business and industry in applying new technology to the problems of pollution. They are interested in developing the idea of Technology Transfer because it embodies a philosophical position on how they want to do business. Through the federal government (including EPA), billions of dollars of research are funded. Communication of results to people who need or could use it however, has been inadequate.

EPA is the largest federal regulatory agency. Most of the federal legislation that they enforce requires coordination with the states. While states ultimately assume the responsibility of implementing federal legislation, EPA maintains oversight responsibilities.

II. Innovation in the Environmental Field

A. Definition

Innovation in the environmental field is the introduction of a new idea, method, or device, or the adaptation of existing technology for new use in waste management. The environmental field is an exciting area in which innovative technology is being applied.

B. Sources of Innovation

Three sources of Innovation:

1. Solution to a problem developed within an organization.
2. Political policies adjusted by government leaders to solve new problems.
3. Communication across programs (within the same organization or between two or more organizations)

C. Receptivity to Innovation

What conditions are required for successful innovation?

Nine conditions were summarized by Manfred Kochen (in Innovation in the Public Sector, ed. by Richard L. and Anna J. Merritt, Sage Publications, Beverly Hills, 1985):

1. Top management supports the innovation, allocating sufficient resources to see it through its critical phases.
2. Open-minded, progressive, middle-level managers of high quality and ability, often with formal technical qualifications, are involved with the innovation in a flat organizational structure that can adapt to change.
3. There is a recognized need and an acceptance of technical potential.
4. The new product or process is followed up with efficient technical service, spare parts, and user training.
5. Innovators collaborate and communicate effectively with potential users from the earliest stage in the innovation process.
6. Efficient research and development testing eliminates most of the bugs prior to marketing.
7. A professional approach to planning and managing the innovation is used.
8. "Key Individuals" such as a product champion, technical innovator, or business innovator may be used.

9. Research and development, production, marketing, and other corporate functions are well coordinated.

D. Barriers to Innovation

Many barriers to innovation exist. Some of these are:

1. Fear of change
2. Radicalness of the change
3. Quality and quantity of information available
4. Selective filtering
5. Length of time required to obtain federal permits
6. Cost of implementation

E. Organizing for Innovation

There are several methods by which innovation can be encouraged within organizations. There is no one best method, rather the structure of the existing organization must be taken into account when reorganizing to incorporate innovation. Some of the methods by which innovation is encouraged within organizations are given below.

1. Organizational structure is made flatter.
2. A specific department within an organization encourages innovation (R & D Labs).
3. External organization which introduces innovation to other organizations (Consulting Firms, EPA).
4. The entire organization is built upon the principle of innovation (an example is the 3M Corporation).

III. Examples of Environmental Technology Transfer

Innovative technology is being applied in many areas of environmental concern. Hazardous waste management is a top priority due to the possible dangers the waste may pose to people. The EPA's SITE Program provides a means of testing innovative technology at Superfund sites. Another area in which innovation is providing solutions to a problem is in the disposal of solid plastic waste. New technology for separating plastics improves the economics of recycling.

A. SITE Programs

Many examples of innovative technology are being developed and tested for use in hazardous waste management. A few innovations currently being tested are:

1. In-situ Vitrification (ISV) is being demonstrated by Geosafe Corporation.
2. Infrared Thermal Destruction is being demonstrated by Haztech.
3. Solidification/Stabilization technology is being demonstrated by Hazcon, Inc.
4. In-situ Vacuum Extraction is being demonstrated by Terra Vac, Inc.

B. Recycling of Plastics

New technology in recycling of plastics is helping to reduce the amount of solid waste that must be disposed of in landfills.

1. ET-1 is a system developed to recycle commingled plastics.
2. Polyethylene terephthalate (PET) is being recycled for use in many products.

CURRICULUM GUIDE
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APPENDICES

APPENDIX I-B

Historical Aspects

Plato was an early proponent of Technology Transfer, although he would not have called it that. He was a hands-on, practical manager with a specialty in diffusing innovation and applying it. His Academy in Athens lasted more than 500 years. How many modern institutions have lasted as long as that? The style of management he presented created the environment for longevity.

Plato was the first administrator to understand the benefits of managing by "wandering around," not being isolated in a large office. Plato also recognized that innovation thrives where questions are posed, not where answers are dictated (the Socratic method). One way to encourage someone to do something is to have them think of the idea themselves through their questions. Plato lectured in small, intimate settings which are more conducive to innovation, and were the predecessor to the latest "skunk works" or "quality circle" concepts. He also realized that beginning a company was different than maintaining one, he invented the assessment center to determine on-the-job performance and he saw the advantages to specialization of labor 2000 years before Adam Smith wrote about it in The Wealth of Nations.

For more classic examples, see "Classical Management Strategies for Public Administrators," by John Clemens and Merrilee Gomillion in Journal of Policy Analysis and Management, v5 Winter 1986 pp 373-77.

APPENDIX I-C

The Idea of Technology Transfer

The underlying philosophy is that Technology Transfer occurs where researchers and practitioners come together to solve their problems jointly. That is, Technology Transfer is not one dimensional; it is an exchange between two parties. For this to be successful, both parties need to benefit. The incentives provide the impetus for inventors to participate in the commercialization of their ideas. That is, to become champions. For new and radical ideas to be successful, they need to be pushed along by champions who will dedicate time and energy to see them through to their conclusion.

Transforming new ideas into commercial products is time consuming and expensive. Roughly 90 percent of the cost of bringing a new product to commercialization is in engineering design, production engineering, start-up costs and marketing, all of which we might consider to be part of Technology Transfer. Only a small proportion of the cost is in product development. This is further justification for focusing on Technology Transfer problems.

NASA has been successful in finding new applications for products that were developed in the space program. Velcro is a well known consumer product with space age origins. NASA is now working with EPA to identify

opportunities for marketing their products and processes in the environmental field. Spacecraft technology could make homes more energy efficient, improve indoor air quality, process human waste products more efficiently and better package foods for long term storage.

In the case of EPA, they have to wrestle with an additional problem. They have to help the developer of a product wind his or her way down the tortuous regulatory path to a permit. Company executives have told EPA that there are many sources of ideas to address pollution and the venture capital is accessible. The problem that they can't deal with is the long gestation period to receive federal approval. Obtaining a permit for using new technology could take up to two years, delaying implementation of the project. The process can be even more devastating to small companies. EPA is trying to respond to this problem and the development of a Technology Transfer program is one avenue toward this end.

APPENDIX I-D

Technology Transfer Legislation

The concern with technology transfer was precipitated by the now familiar concern that the United States has fallen in its technical expertise. In some cases, other countries have used U.S. technologies more efficiently and more consistently than the U.S. industries have. Congress' first step was to decide that since the United States government and private industries had created and produced significant inventions, they should begin communicating with each other and share this information. The Stevenson-Wydler Technology Innovation Act of 1980 (15 U.S.C. 3701) and the Patent and Trademark Amendments of 1980 (15 U.S.C. 200) paved the way for the recent legislation in the Technology Transfer Act of 1986 (P.L. 99-502, October 20, 1986). President Reagan also signed the Executive Order 12591, "Facilitating Access to Science and Technology," which contributed to these efforts.

Before 1980 the government had the option to retain title rights to all federally funded inventions, although these rights could be waived under certain conditions. This practice might lend itself to the federal government holding onto its inventions even if the material is not sensitive or top secret. Legislation, beginning in 1980, began to chip away at these impediments so that others could see first what is being produced, and second to actually be able to use the inventions. Five major legislative actions by the federal government have addressed technology transfer.

Legislation passed so far includes:

1. Stevenson-Wydler Technology Innovation Act of 1980 (15 U.S.C. 3710)
2. Patent and Trademark Amendments of 1980 (15 U.S.C. 200)
3. Technology Transfer Act of 1986 (P.L. 99-502)
4. Executive Order 12591, "Facilitating Access to Science and Technology" (1987)
5. Superfund Innovation Technology Evaluation (SITE) set up by the Superfund Amendments and Reauthorization Act of 1986 (SARA)

1. The Stevenson-Wydler Act of 1980 directed all federal laboratories to establish an office of research and technology applications so that information about innovations coming from the government could be routed to those who might need the information.

2. The Patent and Trademark Amendments encouraged the licensing of government-operated laboratory inventions by authorizing federal agencies to grant exclusive and partially exclusive licenses if the agency determines that it is appropriate and in the public interest. The Patent and Trademark Amendments of 1980, as amended, have divided the Department of Energy's (DOE'S) contractor-operated laboratories into three categories for purposes of technology transfer:

1. DOE's research laboratories operated by universities, including Argonne National Laboratory and Brookhaven National Laboratory, are authorized to retain title to almost all inventions.

2. DOE's research laboratories operated by large businesses, including Oak Ridge National Laboratory and Idaho National Engineering Laboratory, cannot elect to retain title to inventions that they make. They have to request a waiver of DOE's invention rights on a case-by-case basis.

3. DOE's contractor-operated laboratories that are primarily dedicated to naval nuclear propulsion or weapons-related research, including Sandia National Laboratories and Lawrence Livermore National Laboratories, are specifically excluded by the Act from taking title to inventions that they make without obtaining DOE approval through a waiver of rights. (GAO report, page 18)

Oak Ridge National Laboratory is concerned about the constraints to technology transfer because of the time delay and uncertainty involved in the invention waiver process. They have appealed to DOE, who drafted and sent changes in the regulations to the Office of Management and Budget (OMB). The Department of Commerce has verified that the regulations are too restrictive to the large-business contractors such as Oak Ridge.

Research managers and technology transfer officials at Sandia and Lawrence Livermore National Laboratories said that they have to request DOE's approval for retaining title rights, entering into work-for-others agreements and entering into collaborative R&D agreements that provide some kind of exclusivity. The review of these activities can take several months and often the business loses interest in working with the laboratory. DOE's goal is to provide a response to the laboratories within six weeks of a patent waiver request.

The officials also requested that DOE give them the authority to enter into agreements without their approval if the amount is for less than $1 million.

3. The most effective mechanism for technology transfer is through direct contact by federal laboratory researchers working with industry and university researchers. The Technology Transfer Act of 1986 is designed to facilitate these efforts. One section of the Act directs laboratory directors to work with businesses who

agree to manufacture the results of the inventions primarily in the United States. The Technology Transfer Act of 1986 amended the Stevenson-Wydler Act to authorize federal agencies to permit their government-operated laboratories to collaborate on R&D with other organizations, including businesses, through a cooperative R&D agreement. Through this, the private sector will be able to facilitate these agreements easily and the government will still be able to protect what it feels necessary. With the Technology Transfer Act of 1986, an employee who markets inventions can receive 15 percent in royalties. However, an employee who markets software is not entitled to any royalty income. Exceptions to disclosure of research-related information under the Act are limited but include classified information and company trade secrets. Because of the limitations to conduct proprietary R&D, technology transfer is hampered. Businesses want their company and research data kept confidential. Business officials suggested changing federal law to authorize federal laboratories to:

1. Conduct proprietary R&D under a cooperative R&D agreement for government-operated laboratories, or under a similar arrangement for contractor-operated laboratories, and

2. Treat the R&D results as a company trade secret for up to five years, depending on the specific research project and the field of technology. (GAO report, page 16)

The problem perceived by the officials was that if this was put into place, it might affect one laboratory's relationship with others in that the usually open exchanges might be restricted so that trade secrets would not be released. Some laboratories suggested that federal agencies should control access to any

laboratory results that are commercially valuable but that if there are nonpatentable trade secrets they could be disseminated.

4. Executive Order 12591 was signed by President Reagan in 1987. It allows the federal government to waive its rights to inventions developed under federally funded programs. The only restriction in this order is that the federal government be able to use the inventions without paying royalties. It also applies to software developments and engineering drawings, not just inventions. The order also encourages sharing of staff and establishment of research centers. The Executive Order, which facilitates access to science and technology, implements the Technology Transfer Act in directing the heads of federal agencies to delegate authority to their laboratories to enter into the R&D agreements. In addition, the agencies have the option to license, assign, or waive rights to intellectual property, including inventions and computer software that is developed by the laboratory. The Order allows federal contractors and grantees to retain rights to computer software and other technical data. Included in this Order was a directive for the Department of Commerce to investigate any problems that would restrict the transfer of federally funded computer software to the private sector and state and local governments.

Software is made available through the Department of Commerce's National Technical Information Service, the Department of Energy's National Energy Software Center at Argonne National Laboratory, or NASA's Computer Software Management and Information Center at the University of Georgia.

5. EPA is encouraging the development of new technology under the Superfund Amendments and Reauthorization Act of 1986 (SARA). The program is called SITE, or Superfund Innovation Technology Evaluation Program. SITE is designed to assist in the development and demonstration stages of new technology. EPA cooperates with developers of clean-up technology by allowing them to test their products on Superfund sites. EPA provides some funding, primarily to analyze the test results. Most of the funding is provided by the developer. Several examples of innovative technology demonstrated in 1988 are:

1. In-situ vitrification is a process to turn contaminated soil into a glass/rock combination.

2. Infrared Thermal Destruction brings organic waste to combustion temperatures and incinerates any remaining waste.

3. Concrete solidification mixes contaminated dirt with cement and water and puts it back on the site.

4. In-situ vacuum extraction removes volatile organic compounds from the vadose or unsaturated zone of soils.

(See Appendix III-A for more details on these technologies)

APPENDIX I-E

Changing Role of the Environmental Protection Agency

The EPA is interested in developing the idea of Technology Transfer because it embodies a philosophical position on how they want to do business. It is an attempt to institutionalize the scientific and technical role of EPA. It is a recognition that EPA should be in the forefront of new technology working with business and industry to solve pollution problems.

At EPA, and in the federal government in general, billions of dollars of research are funded. The EPA does $100 million a year in contract R&D. In 1986 the EPA established the Superfund Innovative Technology Evaluation (SITE) Program. SITE is designed to promote development and use of innovative technologies to clean up hazardous waste sites across the country. The SITE Program is composed of three related programs: 1) the Demonstration Program, 2) the Emerging Technologies Program, and 3) the Measurement and Monitoring Technologies Program. SITE is helping provide treatment technologies that meet strict federal and state cleanup policies. The technologies being tested are attempting to provide permanent solutions to waste management, rather than quick, temporary fixes.

Another area where EPA has been working to develop new ideas is in a program called Innovative and Alternative

Technology. This is part of the grant program to finance sewage treatment plant construction. Municipalities proposing innovative projects could receive a greater proportion of their funding from EPA than for conventional technology (e.g., 85% vs. 65% funding). While the grant program is no longer significant, technical assistance is being provided for innovative projects.

Under the Reagan Administration the grant program has declined. Communities that were building waste water treatment factories with federal dollars are not prepared to assume that financial burden on their own. They are looking for new innovations to reduce treatment costs. Artificial marshes are one of the innovative ideas being pursued as cost reducing technology.

EPA is the largest federal regulatory agency. Most of the federal legislation that they enforce requires coordination with the states. The states ultimately assume responsibility for implementation; EPA maintains some oversight responsibilities to assure the Congress that federal dollars are being spent correctly. EPA also has to certify that the state laws are equivalent to federal laws so that companies with pollution problems will not have an incentive to move from one state to another to avoid tough legislation. The environmental lobbyists, and sometimes industry lobbyists, are quick to criticize EPA when they falter in their role to maintain consistency.

Most of the legislation administered by EPA has been around for several years. During this time, the states have had time to pass their own laws to implement the national programs. EPA's responsibility for direct implementation is therefore reduced. On the other hand, their role of providing support to the states and to local governments is expanded. EPA sometimes supports the states by taking a lead on interstate problems, or problems polarized by local politics; and in some cases they work jointly on projects with state counterparts. In EPA's oversight role, they conduct audits and provide assistance in dealing with the problems uncovered.

The reason for the strong response to this new program initiative from EPA is to improve technical assistance in the environmental field. EPA's role of providing technical assistance is to assist the states in their enforcement program; and work with business and industry to make technological changes to comply with new environmental requirements in the law. It is the classical carrot and stick form of motivation. The regulatory agencies impose fines and take polluters to court as part of their strong enforcement posture. At the same time, they try to face the reality that compliance ultimately will be only as good as our economy can afford. Good technical assistance on how to comply with the law will ultimately make compliance more affordable and make a higher level of compliance feasible.

The less that EPA is involved in direct implementation and the more they assist the states, the more they need to be in the forefront of new environmental technology. Through cooperation with the Office of Research and Development (ORD) EPA wants to bring information and training to their own staff and to the staff of their counterpart agencies at the state and local levels.

APPENDIX II-B

Sources of Innovation

The first way in which innovation can arise is as a solution to a specific problem. When a problem is identified organizations may respond in several ways at once. Program goals may be adjusted or reworded to alert those concerned about what the organization is doing; and it is the responsibility of staff members to derive solutions to the problems posed. With changes in philosophies come substantial changes in methodology, or how the program will be actualized.

When an organization becomes aware of a problem and the solution does not accompany it, the solutions come from the experience and innovation of the employees of the organization. This is a process of communication as well, because as the problem is communicated through the ranks it passes through a number of people, some of whom will add their own ideas. The broader the problem, the more will the solution be affected by the numbers and diversity in the people among whom it is circulated.

Innovation can also arrive when political leaders recognize new problems and adjust policies to meet those perceived needs. One way is to work with constituency or pressure groups to create support. An example of this found at the EPA. The EPA is credited with having created nationwide grass-roots support for its clean water

regulations by establishing local boards to determine the level of water purity required.

The third source of innovation comes from communication across programs. This may occur within an organization or between two organizations. Two organizations may establish linking mechanisms for policy making and service delivery. This is one way of coping with limits on growth imposed by the political system.

APPENDIX II-E

Structuring Innovation

This section will examine how organizations can encourage or discourage innovation. A flat organizational structure, where hierarchy is not as important and there is freedom to communicate directly with someone at the same level is more conducive to innovation.

The tallness or flatness of an organization's hierarchy depends on several factors. First, the more complex the interdependencies, among activities within the organization, the taller the hierarchy is likely to be. With more complicated relationships and more specialization, it generally follows that more people are necessary to understand and manage the activities. Second, the greater the uncertainty regarding the organizations activities, the flatter the hierarchy is likely to be. With more uncertainty, it is more difficult to be able to specialize and communication becomes more important. This is essential because:

1. Each official must be free to coordinate directly with a great many others in unpredictable ways, so formal channels cannot be set up in advance.
2. The need for dialogues among officials and for constant redefining of tasks makes working through intermediaries inefficient.
3. Communications among officials who have about the same status are less likely to

be inhibited than those among officials on different levels.

4. Coping with highly uncertain tasks requires very talented specialists who can be retained in the organization only if they are given relatively high status and responsible positions incompatible with a many-level hierarchy.
5. Talented specialists working under novel conditions often know more than their supervisors about how to coordinate their activities.

There is a journal published by the American Management Association called Intrapreneurial Excellence that is devoted to nurturing the creative spirit within organizations. In "Goodbye, Corporate Hierarchy," an article in the December, 1987 issue, a new style of management which involves corporate entreprenuers who practice networking is discussed. This management style enables individuals to link up to get a job done, then break away, and link up with new people when a new project is proposed.

The journal also recommends steps to facilitate entrepreneurialism. It suggests that while it is important to allow extra space, there also needs to be a clear direction to follow. Employees should be trained to think and behave entrepreneurially. Active user involvement should be encouraged and experiments should be on a small scale so that mistakes are inexpensive. Also suggested was that more than one group should be involved on one goal In addition, the company should use event-based budgeting and check with the group to make sure that the system will accept new information. In addition, the supervisor should not interfere and be generous with seed money so that many

entrepreneurs with the same organization can obtain it. Finally, entrepreneurs should not be appointed. An excellent example of a company that encourages their employees to be entrepreneurs is 3M Co. of St. Paul, Minn. (See the accompanying article on 3M taken from the April 10, 1989 issue of Business week.)

MASTERS OF INNOVATION

HOW 3M KEEPS ITS NEW PRODUCTS COMING

It was 1922. Minnesota Mining & Manufacturing inventor Francis G. Okie was dreaming up ways to boost sales of sandpaper, then the company's premiere product, when a novel thought struck him. Why not sell sandpaper to men as a replacement for razor blades? Why would they risk the nicks of a sharp instrument when they could rub their cheeks smooth instead?

The idea never caught on, of course. The surprise is that Okie, who continued to sand his own face, could champion such a patently wacky scheme and keep his job. But unlike most companies then—or now—3M Co. demonstrated a wide tolerance for new ideas, believing that unfettered creative thinking would pay off in the end. Indeed, Okie's hits made up for his misses: He developed a waterproof sandpaper that became a staple of the auto industry because it produced a better exterior finish and created less dust than conventional papers. It was 3M's first blockbuster.

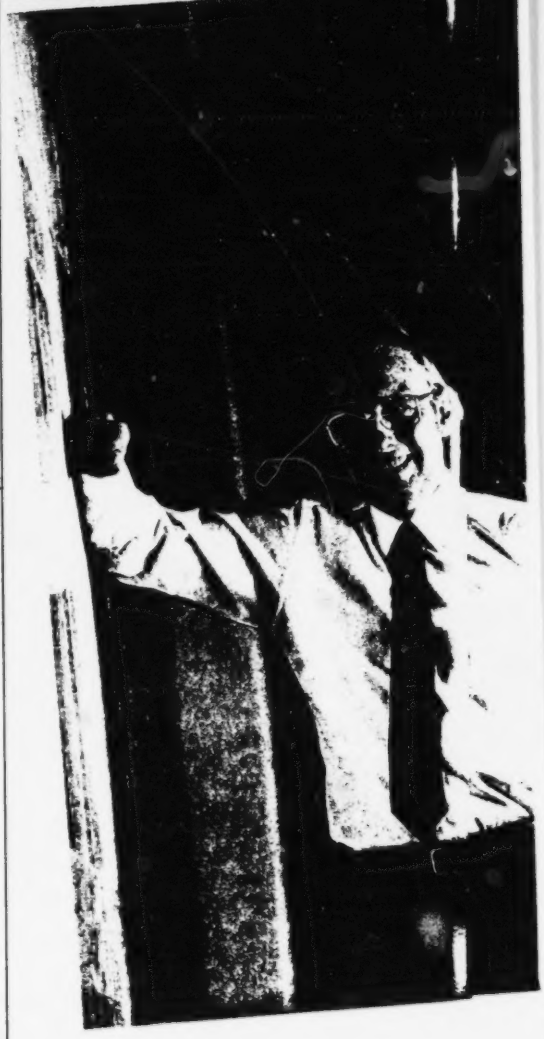
Through the decades, 3M has managed to keep its creative spirit alive. The result is a company that spins out new products faster and better than just about anyone. It boasts an impressive catalog of more than 60,000 products, from Post-it notes to heart-lung machines. What's more, 32% of 3M's $10.6 billion in 1988 sales came from products introduced within the past five years. Antistatic videotape, translucent dental braces, synthetic ligaments for damaged knees, and heavy-duty reflective sheeting for construction-site signs are just a few of the highly profitable new products that contributed to record earnings of $1.15 billion in 1988.

At a time when many big U.S. corporations are trying to untangle themselves from bureaucracy, 3M stands apart as a smooth-running innovation machine. Along with a handful of other companies that might be called the Innovation Elite—Merck, Hewlett-Packard, and Rubbermaid among them (page 62)—3M is celebrated year after year in the rankings of most-respected companies. Business schools across the country make 3M a case study in new-product development, and management gurus trumpet 3M's methods. Peter Drucker's *Innovation and Entrepreneurship* is peppered with 3M tales. A star of the bestseller *In Search of Excellence*, 3M remains a favorite of coauthor Thomas J. Peters. "It is far more entrepreneurial than any $10 billion company I've come across," he says, "and probably more entrepreneurial than a majority of those one-tenth its size."

The publicity has attracted representatives of dozens of companies from around the world to tour 3M headquarters near St. Paul, Minn., in search of ideas and inspiration. While such companies as Monsanto Co. and United Technologies Corp. have adopted some of 3M's methods, it's hard to emulate a culture that has been percolating since the turn of the century.

LOSE SOME. So how does 3M do it? One way is to encourage inventive zealots like Francis Okie. The business of innovation can be a numbers game—the more tries, the more likely there will be hits. The scarcity of corporate rules at 3M leaves room for plenty of experimentation—and failure (page 62). Okie's failure is as legendary among 3Mers as his blockbuster. Salaries and promotions are tied to the successful shepherding of new products from inception to commercialization. One big carrot: The fanatical 3Mer who champions a new product out the door then gets the chance to manage it as if it were his or her own business.

Since the bias is toward creating new



PAYOFF ▶ Tony Flannery developed a filter for metalworking shops—a mere $1 million market. R&D funds led him to markets 20 times bigger

THE TRANSPARENCY OF CELLOPHANE TAPE (UPPER LEFT) PATRICIA MILHAILL ABRAMSON MITCH KEZAR MICHAEL L ABRAMSON WORLDPICTURE GROUP

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TAKING AN IDEA AND RUNNING WITH IT

▲ **HIGH NOTES**
Post-its, demonstrated by 3M engineers Art Fry, left, and Spencer Silver, began life as a way to keep bookmarks from slipping out

◀ **R&D FIRST**
Jake Jacobson has cracked a tough nut by cutting costs without hurting R&D efforts

▲ **SHINER**
Sanford Cobb won an in-house grant to develop the use of plastic film in lighting—a profitable breakthrough

products, anything that gets in the way, whether it's turf fights, overplanning, or the "not-invented-here" syndrome, is quickly stamped out. Divisions are kept small, on average about $200 million in sales, and they are expected to share knowledge and manpower. In fact, informal information-sharing sessions spring up willy-nilly at 3M—in the scores of laboratories and small meeting rooms or in the hallways. And it's not unusual for customers to be involved in these brainstorming klatches.

PEER REVIEW. That's not to say that corporate restraint is nonexistent. 3Mers tend to be self-policing. Sure, there are financial measures that a new-product team must meet to proceed to different stages of development, but the real control lies in constant peer review and feedback.

The cultural rules work—and go a long way toward explaining why an old-line manufacturing company, whose base products are sandpaper and tape, has become a master at innovation. And a highly profitable one at that. Earnings spurted 25% in 1988 from a year earlier. It wasn't always so. The company hit a rocky stretch in the early 1980s. But stepped-up research spending and some skillful cost-cutting by Chairman and Chief Executive Allen F. Jacobson have revived all of 3M's critical financial ratios.

A 3M lifer and Scotch-tape veteran, Jake Jacobson took over the top job in 1985 and laid out his J-35 program. That's J as in Jake, and 35 as in 35% cuts in labor and manufacturing costs—to be accomplished by 1990. 3M is well on its way to reaching those goals, and the push has already improved the bottom line. Last year return on capital climbed almost three points, to 27.6%, and return on equity had a similar rise, to 21.6%. Jacobson has clamped down on costs without harming his company's ability to churn out new products one whit.

MOTLEY CREW. 3M was founded not by scientists or inventors but by a doctor, a lawyer, two railroad executives, and a meat-market manager. At the turn of the century the five Minnesotans bought a plot of heavily forested land on the frigid shores of Lake Superior, northeast of Duluth. They planned to mine corundum, an abrasive used by sandpa-

3M'S PUSH FOR PRODUCTS AND PROFIT
MORE RESEARCH SPENDING...
R&D AS A PERCENTAGE OF SALES
TOTAL SALES '88: $10.6 BILLION
TOTAL PROFIT: $1.15 BILLION
'80 '81 '82 '83 '84 '85 '86 '87 '88
PERCENT
...HELPS THE BOTTOM LINE
ANNUAL GROWTH RATE
PERCENTAGE CHANGE IN EARNINGS PER SHARE
DATA: 3M CO.

PHOTOGRAPH BY JOHN MCGRAIL. CHART BY JOHN DECKERT

per manufacturers to make the paper scratchy. The five entrepreneurs drummed up new investors, bought machinery, hired workers, and started mining. Only then did they discover that their corundum, alas, wasn't corundum at all but a worthless mineral that the sandpaper industry wanted no part of.

The company tried selling its own sandpaper, using corundum shipped in from the East, but got battered by the competition. How perfect: The company that tolerates failure was founded on a colossal one. 3M was forced to innovate or die. Most of the original investors got swept out of the picture, and the remaining 3Mers set about inventing. First, the company introduced a popular abrasive cloth for metal finishing. Then Okie struck gold with his Wetordry sandpaper. They drew inspiration from William L. McKnight, who is revered to this day as the spiritual father of the company. He started out as an assistant bookkeeper and worked his way up through sales. His approach, unusual for its day, has stuck with the company. Rather than make his pitch to a company's purchasing agent, McKnight talked his way onto the factory floor to demonstrate his products to the workers who used them. After he became chairman and chief executive, he penned a manifesto that said, in part: "If management is intolerant and destructively critical when mistakes are made, I think it kills initiative."

LOYAL LIFERS. That kind of thinking breeds loyalty and management stability. The company rarely hires from the outside, and never at the senior level. Jacobson, 62, a chemical engineer, started out in the tape lab in 1947. And all his lieutenants are lifers, too. The turnover rate among managers and other professionals averages less than 4%. "It's just not possible to really understand this company until you've been around for a long while," says Jerry E. Robertson, head of the Life Sciences Sector.

Don't let 3M's dull exterior fool you. The St. Paul campus, home of company headquarters and most of the research labs, is an expanse of brick buildings with a high-rise glass tower that could have been designed by a kid with an Erector set. But inside is an army of engineers and technical experts and platoons of marketers just raring to innovate.

Here's how it typically works: A 3Mer comes up with an idea for a new product. He or she forms an action team by recruiting full-time members from technical areas, manufacturing, marketing, sales, and maybe finance. The team designs the product and figures out how to produce and market it. Then it develops new uses and line extensions. All members of the team are promoted and get raises as the project goes from hurdle to hurdle. When sales grow to $5 million, for instance, the product's originator becomes a project manager, at $20 million to $30 million, a department manager, and in the $75 million range, a division manager. There's a separate track for scientists who don't want to manage.

MANY PATHS. As a result, 3M is big but acts small. There are 42 divisions, so ladders to the top are all over the place. Jacobson reached the pinnacle by cleaning up old-line operations, while his predecessor, Lewis W. Lehr, invented

INSPIRATION FROM THE PLANT FLOOR

When I worked as a tape slitt at 3M, we called them The Ti They were the buttoned- members of the 3M Co. quality contr team who would occasionally venture or the grimy factory floor.

"They were the bad guys," says L Vernon, who runs a slitting machine th converts huge rolls of tape into the sm ones you buy in the store. "They used tell you rather than listen to you, assu ing they even spoke to you in the fi place." I worked alongside Vernon years ago, running my own machine, sl ting masking tape so I could come up wi college tuition. 3M paid me well and, the standards of the day, treated me w But despite all the talk I had heard abo 3M and innovation, nobody ever asked r for ideas on how to do my job better least of all the guys from quality contr

That was 1973. Today, 3M's tape bu ness is under assault from Japanese a European manufacturers. Over the yea while researchers at headquarters in

Paul spewed out new products, innovation in 3M's factories lagged. By the early 1980s costs were out of control, and quality wasn't up to snuff. Productivity became a top priority for Chairman and CEO Allen F. Jacobson, who worked his way up through the tape division. By 1990, he aims to cut labor and manufacturing costs by 35% each.

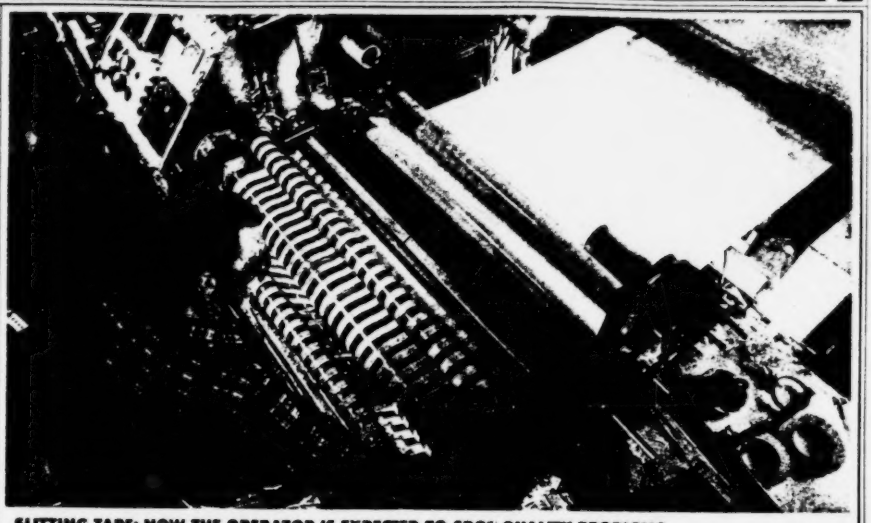
ON A ROLL. The edict forced major change at 3M's far-flung factories. At its tape plant in Bedford Park, a Chicago suburb, Vernon is in charge of his own quality now. "The difference," he says, "is night and day."

The manufacturing process has been completely overhauled. Tape is made by coating a backing with adhesive and creating a giant roll about the size of an office desk. These "jumbos" are then taken to slitting machines. Until recently, all tape at the plant—masking tape, industrial tapes, closure tape for diapers—was coated in one area and transported for slitting to the other end of the factory. The coating and slitting functions had separate supervisors, and they didn't always communicate well. Production rates weren't coordinated, and hundreds of jumbos were stockpiled throughout the plant.

Now slitters are placed near the coaters, and management duties are determined by product line, not function—that is, a supervisor will be in charge of masking tape, not just coating or slitting. The new setup puts a lot more responsibility on the shoulders of individual workers. A slitting operator is expected to identify quality problems immediately so he or she can have the coater stopped after only two or three bad jumbos are produced, rather than the dozens botched in the past. As a result, inventory has been trimmed dramatically. And manufacturing time has improved by two-thirds.

The workers with whom I talked appreciate the new responsibilities. I had hated feeling like an automaton when I worked in the 3M plant, but it's an entirely different story these days for my former colleagues. They don't miss The Ties at all.

By Russell Mitchell in Bedford Park, Ill.



SLITTING TAPE: NOW THE OPERATOR IS EXPECTED TO SPOT QUALITY PROBLEMS

a surgical tape and then rode the company's burgeoning health care business all the way to the chairman's post.

So what are the corporate guidelines? A prime one is the 25% rule, which requires that a quarter of a division's sales come from products introduced within the past five years. Meeting the 25% test is a crucial yardstick at bonus time, so managers take it seriously. When Robert J. Hershock took over the occupational health division in 1982, it was utterly dependent on an aging product category, disposable face masks. By 1985 his new-product percentage had deteriorated to a mere 12%.

That set off alarms. He and his crew had to come up with plenty of new products—and they had to do it in 18 to 24 months, half the normal time. Using technology similar to the division's face-mask filters, Hershock's action teams created a bevy of products. One team came up with a sheet that drinks up the grease from microwaved bacon. Another devised a super-absorbent packing material that was widely welcomed by handlers of blood samples. The idea came from a team member who had read a newspaper article about postal workers who were panicked by the AIDS epidemic. The division's new-product sales are back above 25%.

Then there's the 15% rule. That one allows virtually anyone at the company to spend up to 15% of the workweek on anything he or she wants to, as long as it's product-related. The practice is called "bootlegging," and its most famous innovation is the ubiquitous yellow Post-it note. Arthur L. Fry's division was busy with other projects, so he invoked the 15% rule to create the adhesive for Post-its. The idea came out of Fry's desire to find a way to keep the bookmark from falling out of his hymn book. Post-its are now a major 3M consumer business, with revenues estimated at as much as $300 million.

CULTURAL HABITS. A new-product venture isn't necessarily limited by a particular market's size, either. Take Scotch tape. It was invented in 1929 for an industrial customer who used it to seal insulation in an airtight shipping package. Who could have known that it would grow into an estimated $750 million business someday?

Another recent example: The market

LIGHTS, ACTION
3M light pipes top off Philadelphia's One Liberty Plaza, far left. Above, employees from various disciplines discuss the design of a respirator

PHOTOS BY MICHAEL L. ABRAMSON

CORPORATE INNOVATORS: HOW THEY DO IT

3M RELIES ON A FEW SIMPLE RULES . . .

Keep divisions small. Division managers must know each staffer's first name. When a division gets too big, perhaps reaching $250 to $300 million in sales, it is split up

Tolerate failure. By encouraging plenty of experimentation and risk-taking, there are more chances for a new-product hit. The goal: Divisions must derive 25% of sales from products introduced in the past five years. The target may be boosted to 30%

Motivate the champions. When a 3Mer comes up with a product idea, he or she recruits an action team to develop it. Salaries and promotions are tied to the product's progress. The champion has a chance to someday run his or her own product group or division

Stay close to the customer. Researchers, marketers, and managers visit with customers and routinely invite them to help brainstorm product ideas

Share the wealth. Technology, wherever it's developed, belongs to everyone

Don't kill a project. If an idea can't find a home in one of 3M's divisions, a staffer can devote 15% of his or her time to prove it is workable. For those who need seed money, as many as 90 Genesis grants of $50,000 are awarded each year

. . . WHILE OTHER COMPANIES HAVE THEIR OWN APPROACHES

RUBBERMAID 30% of sales must come from products developed in the past five years. Looks for fresh design ideas anywhere; now trying to apply the Ford Taurus-style soft look to garbage cans. A recent success: stackable plastic outdoor chairs

HEWLETT-PACKARD Researchers urged to spend 10% of time on own pet projects; 24-hour access to labs and equipment; keeps divisions small to rally the kind of spirit that produces big winners such as its LaserJet laser printer

DOW CORNING Forms research partnerships with its customers to develop new products such as reformulations of Armor-All car polishes and Helene Curtis hair sprays

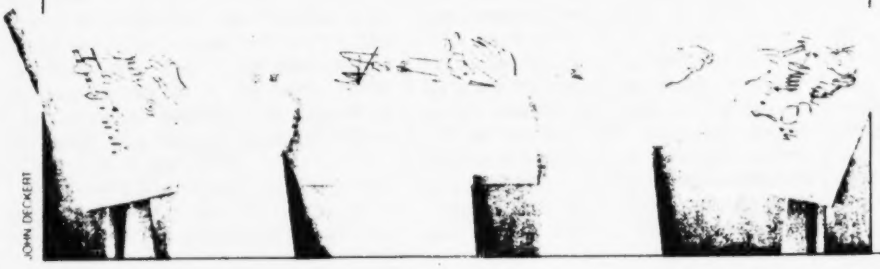
MERCK Gives researchers time and resources to pursue high-risk, high-payoff products. After a major scientific journal said work on anticholesterol agents like Mevacor would likely be fruitless, Merck kept at it. The drug is a potential blockbuster

GENERAL ELECTRIC Jointly develops products with customers. Its plastics unit created with BMW the first body panels made with thermoplastics for the carmaker's Z1 two-seater

JOHNSON & JOHNSON The freedom to fail is a built-in cultural prerogative. Lots of autonomous operating units spur innovations such as its Acuvue disposable contact lenses

BLACK & DECKER Turnaround built partly on new-product push. Advisory councils get ideas from customers. Some new hot sellers: the Cordless Screwdriver and ThunderVolt, a cordless powertool that packs enough punch for heavy-duty construction work

DATA: COMPANY REPORTS



JOHN DECKERT

for 3M chemist Tony F. Flannery's new product, a filter used to clean lubricants in metalworking shops, was a mere $1 million. But Flannery got the go-ahead to dabble with it anyway. He hooked up with a customer, PPG Industries Inc., which sells paint-primer systems to auto makers. The filters they were using to strain out impurities weren't doing the job. Flannery made prototypes of filter bags using a fibrous 3M material. They not only turned out to be bang-up primer filters, but the new bags are also being used to filter beer, water, edible oils, machine oil, and paint. Flannery figures that the filters could become a $20 million business in a few years.

Getting close to the customer is not just a goal at 3M—it's an ingrained cultural trait. Back in the 1920s, 3M inventor Richard G. Drew noticed that painters on automobile assembly lines had trouble keeping borders straight on the two-tone cars popular at the time. He went back to the lab and invented masking tape.

IN-HOUSE GRANTS. Even with 3M's emphasis on innovation, new ideas do fall through the cracks. In 1983 some employees complained that worthwhile projects were still going unnoticed despite the 15% rule. Guaranteed free time doesn't guarantee that there will be money to build a prototype. So the company created Genesis grants, which give researchers up to $50,000 to carry their projects past the idea stage. A panel of technical experts and scientists awards as many as 90 grants each year.

One recipient was Sanford Cobb, an optics specialist at 3M. In 1983 a bulb went on in his head at a scientific conference when he ran across something called light pipe technology. Plastic is inlaid with nearly microscopic prisms so it can reflect light for long distances with little loss of energy.

Cobb knew the heavy acrylic used in the original invention was impractical because it would be difficult to mold, but he figured he could use 3M technology to make a light pipe out of a flexible plastic film. Because 3M isn't in the lighting business, though, Cobb couldn't find a division manager willing to fork over prototype money. So he applied for a Genesis grant. He got it, and made his idea work.

CITY LIGHTS. 3M licensed the basic technology from the inventor, and now its light pipes are used in products offered by several divisions. One use is in large highway signs. The new ones feature two 400-watt bulbs, replacing 60 to 70 fluorescent tubes. Manufacturers of explosives use light pipes to illuminate their most volatile areas. And the top of One Liberty Plaza, the new

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FALSE START
Prospective stockholders on a 1903 inspection tour of 3M's land. The corundum, alas, proved to be no such thing

office tower dominating Philadelphia's skyline, is decorated with a light-piping design. Cobb's development is part of a major new technology program at 3M, with potential annual revenues amounting to hundreds of millions of dollars.

It's a surprise, given 3M's strong predilection toward divisional autonomy, that its technology gets spread around. But 3M is a company of backscratchers, eager to help fellow employees in the knowledge that they'll get help when they need it in return. For example, when the nonwoven-fiber experts got together with the lab folks at abrasives, the result was Scotch-Brite scrubbing sponges. A Technology Council made up of researchers from the various divisions regularly gets together to exchange information.

The result of all this interconnection is an organic system in which the whole really is greater than the sum of its parts. It's no coincidence that 3M is never mentioned as a possible breakup candidate. Bust it apart, sever the interconnections, and 3M's energy would likely die. Even if a raider decided to leave it intact, an unfamiliar hand at the helm might send the company off course. The possibility of a raid on 3M was taken a bit more seriously in the early 1980s, when financial performance slipped as the result of a strong dollar and skimping on R&D in the 1970s.

Jacobson's cost-cutting has done wonders for 3M. But his next challenge is formidable. The company's fortunes tend to track the domestic economy, so with a slowdown on the horizon, he must now find ways to spur growth. For one, he wants to expand internationally, boosting overseas sales from 42% of revenues to 50% by 1992. It may be slow going, however. Just as Jacobson was about to win a beachhead for a plethora of 3M products by buying the sponge unit of France's Chargeurs, the French government blocked the sale on antitrust grounds.

Jacobson is also starting to insist that 3M's divisions develop bigger-ticket products. The company has been taking core technologies and coming up with hundreds of variations. But those market niches can be pretty skinny—often only a few million dollars or so. Now the company's strategists are focusing on 45 new product areas, each with $50 million in annual sales potential three to five years out. One example: A staple gun that replaces pins for broken bones. A 50% new-product success rate would contribute $1.2 billion in sales by 1994 from this program alone.

SINCERE FLATTERY. Jacobson's latest achievements have yet to be reflected in 3M's stock price, which has been hovering in the 60s since the 1987 crash. Analysts are concerned that despite the company's diversification into health care, it still makes about 40% of its sales to the industrial sector, so it could get socked in a recession. And 3M is still considered vulnerable in floppy disks and videotape and related media, which account for about $800 million in sales. The unit has been locked in a bruising battle with the Japanese for years, and lost an estimated $50 million in 1987. While those products finally became profitable in last year's fourth quarter as a result of cost-cutting and wider distribution, the area could remain a trouble spot. "It's a fragile turnaround," says analyst B. Alex Henderson at Prudential Bache Securities Inc.

Other companies would love to have 3M's problems if its successes came with them. Indeed, 3M constantly finds itself playing host to companies trying to figure out how to be more creative. Monsanto has set up a technology council modeled on 3M's, and United Technologies has embarked on an effort to share resources among its not-so-united operations. Eight years ago, Rubbermaid Inc. began insisting that 30% of its sales come from products developed in the previous five years.

While other companies may pick up ideas piecemeal from 3M, it would be impossible for any big corporation to swallow the concept whole. "We were fortunate enough to get the philosophy in there before we started to grow, rather than trying to create it after we got big," says Lester C. Krogh, who heads research and development. 3M has a *simple formula: Find the Francis Okies,* and don't get in their way. But for managers of other companies, large and small, that's often easier said than done.

By Russell Mitchell in St. Paul, Minn.

APPENDIX III-A

SITE Programs

The examples of innovative technology given in the curriculum outline are described in the EPA Technology Profiles on the following pages.

1. Geosafe Corporation is demonstrating in-situ vitrification.
2. Haztech is demonstrating infrared thermal destruction.
3. Hazcon, Inc. is demonstrating solidification/ stabilization technology.
4. Terra Vac, Inc. is demonstrating in-situ vacuum extraction.

EPA Technology Profile
Demonstration Program

SITE
SUPERFUND INNOVATIVE TECHNOLOGY EVALUATION

November 1988

GEOSAFE CORPORATION

TECHNOLOGY DESCRIPTION: In-Situ Vitrification (ISV) is based on the concept of joule-heating to electrically melt soil or sludge. Melt temperatures, in the range of 1600 to 2000°C, act to destroy organic pollutants by pyrolysis. Inorganic pollutants are immobilized within the vitrified mass. Both the airborne organic and inorganic combustion by-products are collected in a negatively pressurized hood which draws the contaminants into an off-gas treatment system that removes particulates and other pollutants of concern.

The ISV technology is trailer-mounted on three semitrailers that are suitable for highway transport. At the site to be treated, the system must be set up on relatively level ground for most effective operation. The vitrification process (Figure 1) is carried out by inserting large electrodes into contaminated zones containing sufficient soil to support formation of a melt. Graphite is placed on the surface to complete the circuit between the electrodes. An electric current is passed through the electrodes and graphite, and the heat generated from this current causes a melt that gradually works downward through the soil. This process permits soil or sludge to be vitrified over an area of approximately 27 feet on a side to a depth of 20 feet and requires seven to ten days to complete. (This is called "one setting"). GeoSafe Corporation has projected vitrification depths to 50 feet with the ultimate limiting factor being melt tonnage per setting. The system is then moved to a second setting where the vitrification process is repeated. This is continued until the entire contaminated soil or sludge volume on the site has been vitrified. The vitrified mass then cools over a period of several months to a year or more.

The basic configuration of the ISV process consists of an electrical network with four electrodes driven or pushed into or placed in drilled augered holes in the soil or sludge, a capture hood to collect fumes or gases from the setting and direct it to an off-gas treatment system, and the off-gas treatment system itself. The off-gas treatment system consists of a quench tower, pH-controlled venturi scrubber, mist eliminator, heater (temperature controller), HEPA filters, and carbon adsorbers.

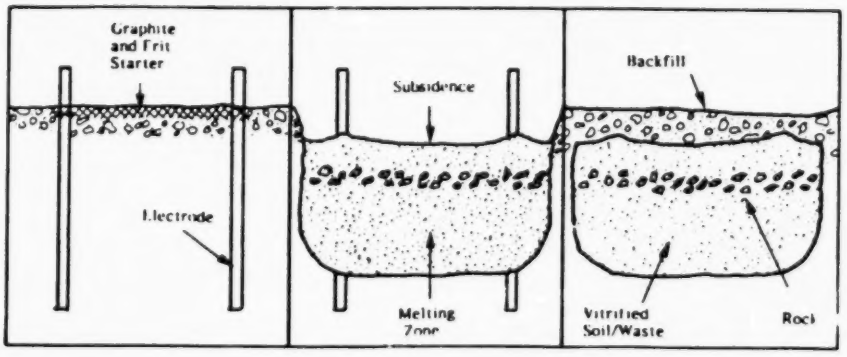

Figure 1. In-situ vitrification process.

The ISV process shares the same process control requirements as other thermal processes that convert hazardous materials into gaseous or vapor form. It is necessary to monitor the process to ensure that the off-gas treatment equipment is properly performing. Because of the high temperature of the melt, the great majority of gases evolving from the melt have been pyrolyzed into low molecular weight molecules or into diatomic gases that do not pose significant hazard to workers or the environment. However, the possibility exists for a small amount of hazardous materials to volatilize from the process; these must be treated by the off-gas treatment system to prevent an uncontrolled release to the environment.

WASTE APPLICABILITY: The ISV process can potentially be used to destroy or volatilize organics and/or immobilize inorganics in contaminated soils or sludges. ISV can be performed on saturated soils, but the initial application of current will be used to volatilize the moisture in the soil or sludge in the vicinity of a starter path of glass frit and graphite. Once this is done, the vitrification process begins. Sludges must contain a sufficient amount of glass-forming material (non-volatile, non-destructible solids) to produce a molten mass that will destroy, remove, or immobilize the organic and inorganic pollutants.

The ISV process is limited by (1) the presence of groundwater in the contaminated soil or sludge with a permeability of greater than 1 x 10^{-5} cm/sec, (2) the presence of buried metals in excess of 5 percent of the melt weight, and (3) the ability to maintain a negative pressure on the off-gas collection hood by the off-gas treatment system, and (4) the amount and concentration of the combustible organics present in the soil or sludge. Each of these limitations should be addressed based on site-specific conditions.

STATUS: The ISV process has been demonstrated at full-scale on radioactive wastes at the Department of Energy's Hanford Nuclear Reservation; pilot tests have also been performed on PCB wastes, industrial lime sludge, dioxins, metal plating wastes and other solid combustibles and liquid chemicals. Identification of a site for this technology demonstration is currently underway.

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EPA Technology Profile
Demonstration Program

SITE
SUPERFUND INNOVATIVE TECHNOLOGY EVALUATION

November 1988

HAZTECH

TECHNOLOGY DESCRIPTION: The electric infrared incineration technology (originally developed by Shirco Infrared Systems, Inc. of Dallas, Texas) is a mobile thermal processing system which uses electrically powered silicon carbide rods to bring the organic waste to combustion temperatures and then, to incinerate any remaining combustibles in an afterburner. The mobile system is comprised of four components: the electric-powered infrared primary chamber, a gas-fired secondary combustion chamber, an emission control system, and a process management and monitoring control center.

Waste is fed into the primary chamber on a wire mesh conveyor belt and exposed (at high temperatures of up to 1850°F) to infrared radiant heat provided by the horizontal rows of electrically-powered silicon carbide rods above the belt (Figure 1). A blower provides air at selected locations along the belt and can be used to control the burning rate of the waste feed and its location while burning on the belt.

The ash material which drops off the belt in the primary chamber is quenched by water sprays. This quench is scrubber water effluent and is used to reduce the amount of scrubber water effluent for disposal or reprocessing. The ash is then screw conveyed out of the primary chamber into the ash hopper where it is removed to a holding area, analyzed for PCB content, and then piled in a new location away from the processing area, after the PCB content is determined to be less than 1 ppm.

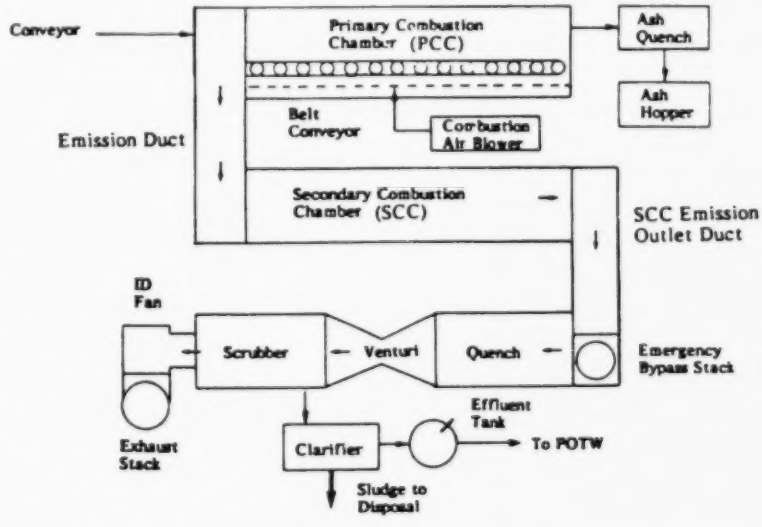

Figure 1. Peak Oil incineration unit process diagram.

Gaseous volatiles from the primary chamber flow into the secondary chamber which at higher temperatures provides residence time, turbulence and supplemental energy (if required) to destroy these gases. Gases from the secondary chamber are ducted through the emissions control system and then exhausted via a stack. An emergency stack is installed prior to the venturi scrubber system so that if the temperature control system and its interlocks were to fail, then the emissions control system would not be melted by the hot gases.

In the emissions control system, the particulates are removed in a venturi section. Acid vapor is neutralized in a packed tower scrubber, and then an induced draft blower draws the cleaned gases from the scrubber into the free standing exhaust stack.

The scrubber liquid effluent then flows into a clarifier where scrubber sludge settles out for disposal. Finally, the scrubber effluent flows to an effluent tank, through an activated carbon filter for reuse, or to a POTW tank for disposal.

WASTE APPLICABILITY: This technology is suitable for organic wastes contained in soils or sediments. Liquid organic wastes can also be handled once they are mixed with sand or soil.

STATUS: Report and summary was published in September 1988. The EPA document number is EPA 540/2-88/002.

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EPA **Technology Profile**

Demonstration Program

SITE SUPERFUND INNOVATIVE TECHNOLOGY EVALUATION

November 1988

HAZCON, INC.

TECHNOLOGY DESCRIPTION: The solidification/stabilization technology mixes hazardous wastes, cement, water and an additive called Chloranan. Chloranan, a nontoxic chemical, encapsulates organic molecules, rendering them ineffective in retarding or inhibiting solidification. This treatment technology immobilizes the contaminants from soils by binding them into a concrete-like, leach-resistant mass.

After contaminated soil is excavated and screened out for oversized material, it is fed to a mobile field blending unit to treat the wastes (Figure 1). The unit consists of soil and cement holding bins, a Chloranan feed tank and a blending auger to mix the waste and pozzolanic materials (portland cement, fly ash or kiln dust). Then, water is added as necessary, and the resultant slurry is allowed to harden before disposal. The treated output are the contaminants bound by encapsulation into a hardened, concrete-like mass. For the treatment of large volumes of waste, larger blending systems are also available.

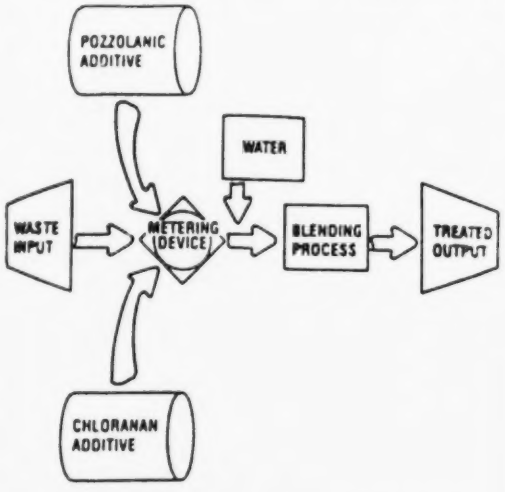

Figure 1. Solidification/stabilization process diagram

WASTE APPLICABILITY: This technology is suitable for soils and sludges contaminated by organic compounds, heavy metals, oil and grease.

STATUS: A former oil reprocessing plant containing high levels of oil and grease along with volatile and semi-volatile organics, PCBs, and heavy metals in Douglassville, Pennsylvania, was selected for demonstration testing using this technology. The Field Demonstration occurred October 1987. A Final Report was completed in September 1988, on the test results for six wastes stabilized at Douglassville.

DEMONSTRATION RESULTS: The comparison of the soil, 7-day and 28-day sample test results were generally favorable. The physical test results were very good, with unconfined compressive strength between 220 to 1570 psi. Very low permeabilities were developed (good) and the porosity of the treated wastes were moderate. Durability test results were very good, there was no change in physical strength after the wet/dry and freeze/thaw cycles. The microstructural analyses seemed to indicate possible sample degradation in the future. The 210-day sample core and future sample core testing will confirm or deny these projections. There was a waste volume increase of about 120%. By using less stabilizer smaller volume increases can be obtained, but lower strengths will result. There is an inverse relationship between physical strength and the waste organic concentration.

The results of the leaching tests were mixed. The TCLP results of the stabilized wastes were very low; essentially all values of metals, volatile organics and semi-volatile organics were below 1 ppm. Lead leachate concentrations dropped by a factor of 200 from the untreated soil results to below 100 ppb. Volatile and semi-volatile organic concentrations, however, did not change from the untreated soil TCLP. Oil and grease concentrations were greater in the treated waste TCLPs than the untreated waste, from less than 2 ppm up to 4 ppm. PCBs could not be detected (< 1 ppb) in the TCLP leachates for either the treated or untreated wastes.

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EPA **Technology Profile**

Demonstration Program

SITE SUPERFUND INNOVATIVE TECHNOLOGY EVALUATION

November 1988

TERRA VAC, INC.

TECHNOLOGY DESCRIPTION: This in-situ vacuum extraction technology is a process for the removal and venting of volatile organic compounds (VOCs) from the vadose or unsaturated zone of soils. Often, these compounds can be removed from the vadose zone before they have a chance to contaminate groundwater. In using this technology, subsurface organic contaminants are "vacuumed up" via a well, vapor/liquid separated, and then exposed to activated carbon before the "vapor" is allowed to be released into the atmosphere.

The technology uses readily available components such as extraction and monitoring well(s), manifold piping, vapor/liquid separator, vacuum pump, and emission control equipment, such as activated carbon canisters. Once a contaminated area is completely defined, an extraction well (or wells) is installed (depending upon the extent of contamination) and is connected by piping to a vapor/liquid separator device (Figure 1). A vacuum pump draws the subsurface contaminants through the well, separator device, and an activated carbon canister before discharge of the air streams is allowed to the atmosphere. Subsurface vacuum and soil vapor concentration are monitored via vadose zone monitoring wells.

The technology does not require highly trained operators or soil excavation, and it also is not depth limited. The technology works best when it is applied towards the remediation at sites which are contaminated by liquids having high vapor pressures. However, the process is limited in applicability; diffusion rates through dense soils (such as compacted clays) are much lower than through sandy soils, and if activated carbon is used, then spent carbon must be processed. In addition, depending on the soil type and the depth to groundwater, the radius of influence of a single extraction well can range from tens to hundreds of feet. Typical contaminant recovery rates also range between 20 and 2500 pounds per day and are a function of volatility of the organic compound recovered. Therefore, the more volatile the organic compound, the faster the process works. The developer also states that the process is more cost effective where contaminated soils are predominantly above the water table, although systems have been designed for vapor and groundwater recovery.

WASTE APPLICABILITY: This technology is applicable to organic compounds that are highly volatile at ambient temperatures in soils and groundwater.

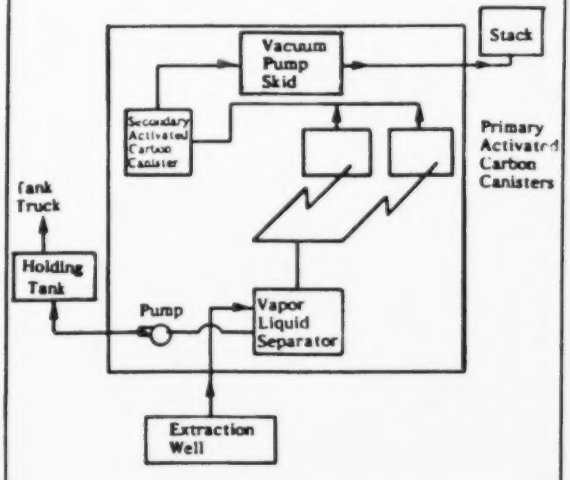

Figure 1. Process diagram for in-situ vacuum extraction.

STATUS: This in-situ vacuum extraction process is being utilized in many locations across the United States, such as the Verona Wells Superfund Site (U.S. EPA Region 5, Battle Creek, Michigan) — which mainly contains trichloroethylene contamination — and several gasoline station spills. Although it was first demonstrated at a Superfund site in Puerto Rico where carbon tetrachloride had leaked from an underground storage tank, a field demonstration of the process was performed under the auspices of the Superfund Innovative Technology Evaluation (SITE) Program and was conducted at the Valley Manufactured Products Company, Inc. property, which is a part of the Groveland Wells Superfund site in Groveland, Massachusetts. This site has been mainly contaminated by trichloroethylene, which was used as a degreasing agent by the machine shop that is still in operation at the site. The technical report from this demonstration project will be published in April 1989.

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APPENDIX III-B

Recycling of Plastics

There are some new innovations in the management of solid plastic waste. ET-1 is an example of innovative technology developed by The Center for Plastics Recycling Research at Rutgers University. ET-1 is a unique process which recycles unsorted plastics.

New uses for recycled plastics, such as polyethylene terephthalate (PET), are being discovered constantly. As the potential uses for recycled plastic increase the demand placed on landfills can be reduced. Many cities have already implemented recycling programs, but as innovative technology provides better methods of recycling and uses for renewable plastics the number amount of waste recycled must be increased.

The fact sheets included here from The Council for Solid Waste Solutions provide additional information on plastics, recycling technology, uses for recycled plastic, and city recycling programs.

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ET-1 Has Landed In The U.S.A.

No. It's not a movie sequel. It is state-of-the-art technology for recycling commingled plastics into useful products. Communities seeking ways to recycle used plastics in the waste stream will benefit from research and development programs now underway at The Center for Plastics Recycling Research, at Rutgers University. ET-1 is just one example of the technologies that are being evaluated at the Center, which was established by the plastics industry, and companies and organizations committed to increasing the rate of plastics recycling nationwide.

Already in commercial use, ET-1 is unique because of its ability to process and recycle mixtures of unsorted plastics previously considered incompatible. Moreover, it tolerates a high volume of some contaminants such as dirt and paper. Technologies to recycle individual types of plastics are in use today and are being refined, but the ET-1 is the first step in developing a system that will allow mixed plastics to be recycled in large amounts, and the plastics industry is researching additional technologies to recycle commingled plastics.

The end product of the ET-1 mixed plastics recycling process is similar to structural lumber. It can be planed, sawed, drilled and screw-connected. And it is immune to damage from water, chemicals, bacteria, insects and rodents. It does not rust. It does not conduct electricity and it will not split or splinter. Because of these special qualities, recycled plastic lumber is now in demand for a wide variety of products:

- docks & piers
- traffic barriers
- curb stops
- fencing
- park benches
- playground equipment

In addition to conserving forest resources, recycling mixed plastics into lumber substitutes can play an important role in solving the solid waste management dilemma in America. For more information on plastics recycling and effective waste management solutions, contact *The Council for SolidWaste Solutions*, a program of The Society of the Plastics Industry, Inc.

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The Facts About Plastics.

The Council for Solid Waste Solutions, a program of The Society of the Plastics Industry, Inc., was established to help formulate solutions to the solid waste management problem because we recognize that plastic products are a part of that problem. We recognize, too, that the actions on solid waste issues that will be initiated during the next decade will directly and dramatically affect the quality of life in this country, and the world.

Here are a few facts most people don't know about plastics:

- Pound for pound, plastic products account for **only about 7%** of municipal solid waste. Yard and food waste, by comparison, account for 29% of the solid waste stream, paper and papberboard 35%.

- Plastic beverage containers have the **second highest "scrap value"** of recyclable materials in packaging -- next to aluminum.

- Plastic products have the **highest energy value** for modern waste-to-energy incineration. For example, the energy content of a pound of polyethylene is 19,900 Btu. A pound of Wyoming coal has an energy value of 9,600 Btu.

- Plastic products have already **contributed substantially to source reduction** in the waste stream by replacing heavier, thicker materials previously used in packaging and through engineered reductions in the amount of plastic used in containers such as the soft drink bottle.

- More than **20%** of all plastic soft drink containers, over 100 million pounds, are already being **recycled** into new consumer products and the demand for recycled plastic is growing. 55 million pounds of the plastic used in milk containers was recycled in 1987.

- Plastic products are popular because they **provide safety and health benefits** for which no other material is equally suited, including tamper-evident foods and medicines, shatter-resistant containers, freezer-to-microwave prepared foods and wrappers that preserve freshness.

For more information about plastics' role in solid waste management, and the steps being taken by the plastics industry to solve the waste management problem, write or call *The Council for Solid Waste Solutions*.

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The Facts About Degradable Plastics.

Research & Results

Plastics are generally resitant to biological attack, a significant advantage in food and beverage packaging. Beginning in the late 1960s and early 1970s, though, research was initiated to develop plastics with enhanced degradability. Most plastics degrade when they are exposed to the ultraviolet rays of the sun, but at a very slow rate. Research into enhancing the degradability of plastics has followed two distinct courses:

1. *photodegradation* -- increasing the susceptibility of plastics to ultraviolet rays; and

2. *biodegradation* -- making plastics less resistant to biological attack.

Photodegradation

Several photodegradation processes have evolved from the research. One specific technology was developed for low density polyethylene, the plastic used in beverage six-pack ring carriers and some grocery bags. Degradability-enhanced six-pack carriers can reduce the risk of wildlife entanglement.

Photodegradation technology has also been developed for other forms of plastic, including polystyrene, polypropylene and linear low density and high density polyethylene.

Biodegradation

In biodegradation, microorganisms such as fungi or bacteria use the plastic material as a food source. In some cases, biodegradable additives like starch are blended with conventional plastic to impart partial biodegradability.

Degradable Products

In addition to six-pack ring carriers, plastic grocery and trash bags with enhanced degradability are now available to consumers in some regions of the country. And degradability-enhanced plastic mulching films are being used by American farmers to reduce the number of weeds, prevent the loss of fertilizer, and limit the rotting of fruit when it comes in contact with the soil.

The Future

Plastics manufacturers are optimistic about future markets for degradability-enhanced products. However, their development must not be at the expense of the environment and effective waste management solutions such as recycling. Research is under way to determine the environmental impact of degradability-enhanced plastics, and their possible effects on recycling technology.

Factors that will influence the future development of degradability-enhanced plastics include: product safety and durability requirements; the potential for waste management benefits and, of course, technology.

Before degradable plastics come into widespread use, uniform definitions and standards for the application of degradation enhancement technology must be developed. No such standards currently exist. *The Council for Solid Waste Solutions*, a program of The Society of the Plastics Industry, Inc., is pursuing the development of such standards.

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The Facts About Polystyrene In The Waste Stream.

In the ten years since polystyrene packaging first became available, it has replaced other materials on supermarket shelves and in fast-food restaurants. Polystyrene is a tough, colorless plastic material, used in making containers such as coffee cups and hamburger "clam shells." Polystyrene foam keeps cold drinks cold and warm foods and drinks warm.

As public officials at all levels of government consider actions to address America's solid waste management problem, a number of facts about polystyrene merit consideration.

- Polystyrene used in food packaging accounts for 0.26% of all total municipal solid waste (MSW) by weight.* Materials that could substitute for polystyrene weigh three to four times more and do not provide the same hot and cold insulating properties.

- Polystyrene is bioresistant; it doesn't degrade easily. When materials degrade after disposal, they can create methan gas and leachate that can contaminate the air and groundwater supplies. Modern landfills are designed to halt degradation and lined to stop leaching into groundwater.

- Chlorofluorocarbons (CFCs) have been a key ingredient used in making some polystyrene products, including foam insulation and some foam food packaging. The industry has been voluntarily moving away from the use of ozone-depleting fully halogenated CFCs for some time in response to concerns about their effect on the Earth's ozone layer. The entire foam foodservice packaging industry voluntarily stopped using ozone-depleting CFCs in 1988. Finding alternatives to fully halogenated CFCs used in the foam insulation industry is a top priority, and research and development efforts are continuing at a rapid pace.

- It takes less energy to produce polystyrene products than products made of other materials.** And, when used in waste-to-energy systems, polystyrene can contribute more energy than its alternatives. The energy content of one pound of polystyrene, when it is used as a fuel source, exceeds that of virtually every other material found in the municipal solid waste stream. The energy produced by waste-to-energy incinerators is a useful by-product that helps to defray the costs of solid waste disposal. Petrochemicals are *borrowed* to make polystyrene, which can then be used as a fuel source after use in packaging.

In addition to being a highly flexible, consumer-friendly material for packaging, polystyrene is preferable to alternative materials in the solid waste stream. It weighs less, does not contribute to leachate contaminants, does not produce toxic methane gas and contributes valuable energy to waste incineration. And, unlike alternatives such as plastic-coated paper, it can be recycled.

For more information about polystyrene, contact *The Council for Solid Waste Solutions*, a program of The Society of the Plastics Industry, Inc.

* Source: Foodservice and Packaging Institute.
**Source: Franklin Associates, Ltd., "Plastics: The Energy Saver," 1978.

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From Soda Bottle to Swimming Pool, Plastics Are Being Recycled.

Technological advances continue to improve the applications for recycled plastic materials. The familiar 2-liter plastic soda bottle, made from polyethylene terephthalate (known as PET) is now being recycled into many products that contribute to the health, safety and well-being of our society.

Recycled PET bottles are now being used in a wide variety of products:

- **scouring pads**
- **paint brushes**
- **fiberfill for:**
  - *-pillows*
  - *-ski jackets*
  - *-cushions*
  - *-sleeping bags*
- **appliance handles**
- **textiles:**
  - *-belts*
  - *-webbing*
  - *-strapping*
  - *-sails*
  - *-woven bags*
- **non-food containers**
- **industrial paints**
- **storage tank insulation**
- **fibers:**
  - *-carpet face yarns*
  - *-carpet backing*
  - *-rope and twine*
  - *-apparel*
- **bath tubs and shower stalls**
- **sinks**
- **boat hulls**
- **geotextiles**
- **automotive components**
- **swimming pools**
- **audio cassette cases**
- **corrugated awnings**

The wide range of properties and applications for plastic resins fosters continual development of new processes, new uses and new products made from recycled materials. Beyond technology, collection of used plastics is key to increasing the level of plastics recycling. The American plastics industry is seeking opportunities to work with community organizations and government leaders to expand the collection of used plastic products for recycling.

For more information on the recycling of PET and other plastics, write or call *The Council for Solid Waste Solutions*, a program of The Society of the Plastics Industry, Inc.

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Recycling Soda Bottles For Spic & Span.

The bottle of Spic & Span Pine you purchase today may have held your favorite soft drink in a former life. Some 20 percent of the plastic soft drink bottles sold in the United States are being recycled into useful products such as carpeting and fiberfill. But now, soda bottles made of polyethylene terephthalate (PET) are being recycled to make new bottles that will hold Spic & Span.

A partnership between the Procter & Gamble Company and Plastipak Packaging, Inc., is bringing a 15-ounce bottle of Spic & Span made from recycled PET to store shelves in the Northwest. This first-ever 100% recycled plastic bottle will be followed by a 28-ounce version.

The future for PET recycling is brighter than ever before. PET's recycling rate is the fastest growing among **all** beverage containers. More than one billion plastic soft drink bottles were recycled in 1988, and with a scrap value that is second only to aluminum among container materials, the PET recycling rate will continue to increase at a record-setting pace.

This is the first step in a long line of recycled plastic developments that we hope the entire packaging industry will undertake. We firmly believe that plastics recycling has a definite role to play in the nation's solid waste management system.

Charles L. Wosaba
Manager, Packaging R&D
Procter & Gamble Co.

But what about other plastics, are they being recycled? Yes. Milk, juice and water containers made of high-density polyethylene (HDPE) are also being recycled at an increasing rate, and technologies for recycling polystyrene foam, vinyl, polyethylene films and mixed plastics are now being utilized in pilot and demonstration projects, as well as commercial operations around the country.

To learn more about plastics recycling, contact *The Council for Solid Waste Solutions*, a program of The Society of the Plastics Industry, Inc.

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Plastics Included in Community Curbside Separation Programs.

The first residential source separation program in the U.S. was instituted by Col. George E. Waring, street cleaning commissioner in New York, in 1896. The program required citizens to separate their garbage into different types so that materials in the waste stream could be treated in a more effective way.

Recycling programs have sprung up in many communities around the U.S. in the past few years, and curbside source separation has increasingly become the mechanism through which these programs are implemented.

As once-used plastic products become more valuable and technologies improve, they are being included more and more in community recycling programs. One and two-liter soft drink bottles made from polyethylene terephthalate (PET), as well as milk and juice containers made from high-density polyethylene (HDPE), are integral in many source separation programs.

From California to New Jersey, these programs are reaping financial and environmental benefits to the communities implementing them.

San Jose, California

In 1985, San Jose started a pilot curbside collection program for 20,000 households. Glass, newspapers and cans were collected and recycled. In August 1987, the program went citywide, and in December of that year, plastic soft drink bottles were added to the program.

Between June and July 1988, monthly plastic bottle collections increased from 2.6 tons to 5.65 tons -- the largest increase since the beginning of the program.

The city's participation for the program now stands at 58%.

Mecklenburg County, North Carolina

Starting in February 1987, 2,400 homes in Mecklenburg County were required to separate newspapers, glass bottles and jars, metal cans and plastic soft drink and liquor bottles. Approximately 9,100 households currently participate in the program.

County officials plan to expand the program to 94,000 homes by September, 1989.

Mount Olive Township, New Jersey

In 1987, Mount Olive became the first New Jersey community to voluntarily start its own recycling program.

At the program's onset, each household was provided with a 7-gallon recycling bucket for separating plastic beverage containers and aluminum cans. Newspapers and glass products are also collected, but stored separately.

For more information on curbside source separation programs, contact *The Council for Solid Waste Solutions*, a program of The Society of the Plastics Industry, Inc.

D-3:2/89

100% recycled paper

Discussion Questions

Appendix I-D

1. How does current legislation enhance environmental technology transfer?
2. How does current legislation inhibit environmental technology transfer?
3. What further legislation should the government enact to promote environmental technology transfer?

Appendix I-E

1. What is technology transfer? How would it apply to agencies other than the EPA?
2. In what ways can technology transfer be encouraged within government, research organizations and industry?
3. What components are necessary for environmental technology transfer programs to work successfully?

Appendix II-E

1. What other sources of innovation are available?
2. Are there any other ways for an organization to encourage innovation?

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